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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : B60C 9/00, 9/20, D02G 3/48		A1	(11) International Publication Number: WO 98/14336
			(43) International Publication Date: 9 April 1998 (09.04.98)
(21) International Application Number: PCT/US97/15402 (22) International Filing Date: 2 September 1997 (02.09.97) (30) Priority Data: 08/726,139 4 October 1996 (04.10.96) US; (71) Applicant: THE GOODYEAR TIRE & RUBBER COMPANY [US/US]; Patent Section - D/823, 1144 East Market Street, Akron, OH 44316-0001 (US). (72) Inventor: REUTER, Rene, Francois; 2 Um Kettenhouscht, L-9142 Burden (LU). (74) Agent: SWISHER, Kathleen, M.; The Goodyear Tire & Rubber Company, Patent Section - D/823, 1144 East Market Street, Akron, OH 44316-0001 (US).			(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  Published With international search report.

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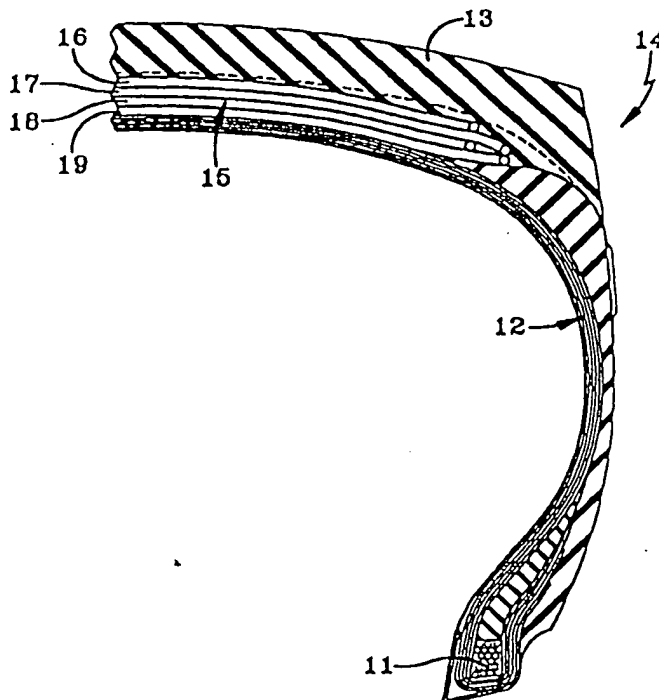
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(54) Title: PNEUMATIC TIRE

(57) Abstract

A pneumatic tire for heavy duty use comprises at least one radial carcass ply, a tread portion disposed radially outwardly of the crown region of the carcass plies and a crown reinforcing structure interposed between the tread portion and the crown region of the carcass plies. The crown reinforcing structure includes a belt assembly having at least a first, radially innermost and a second, radially outermost belt ply. The cords reinforcing the belt plies are preferably made of PET or PEN and have a linear density comprised between 2000 and 16000 Denier, a twist comprised between 2 and 7 TPI and a twist multiplier comprised between 3 and 5.



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PNEUMATIC TIRE

5 The present invention relates generally to textile  
cords for pneumatic tires and more specifically to cords  
for belts of radial carcass tires for heavy duty use.

Radial carcass tires, especially off-the-road tires  
and heavy duty off-the-road tires have typically 1 to 5  
10 carcass plies, 2 to 6 belt plies and one to four sets of  
beads.

Off-the-road tires, because of the nature of their  
use, are exposed to cutting and delamination caused by  
sharp rocks and uneven terrain. This problem is addressed  
by providing such tires with belts reinforced with high  
15 strength material.

One reinforcement cord currently used in belts of  
heavy duty industrial tires is composed of 3 yarns of  
aramid, having a linear density of 1500 Denier, the yarns  
and the cord being twisted at 6.9 turns per inch (TPI).  
20 Such cord has a strength of about 750 N. Aramid is high  
cost to manufacture and to process.

Another reinforcement cord currently used in belts of  
agricultural tires is composed of 2-3 yarns of rayon,  
having a linear yarn density of 1650 to 2200 Denier, the  
25 yarns and the cord being respectively twisted at about  
9 TPI and 6.5 TPI. Such cords have strengths of about  
180 N and 350 N respectively. This cord is high cost to  
manufacture because of high material cost, and the cord is  
subject to moisture pick-up and the cord has a low  
30 tenacity.

Polyester cords, such as 2.000/2 6/6 or 1.000/2 12/12  
TPI which have respectively twist multipliers of 5.2 and  
7.35 are also currently used to reinforce belt plies of  
farm tires. The high twist levels of between 6 and 12 TPI,  
35 however, do not take full advantage of the dimensional  
stability, the modulus, the shrinkage, and the tensile  
strength of the polyester material. The material cost for

- 2 -

this material is also high.

It an object of the present invention to provide a cord with high tensile strength, high modulus, high dimensional stability and low gauge, while maintaining sufficient fatigue resistance, and which is less expensive to manufacture and to process than a cord used in the prior art.

#### Summary of the Invention

10 A polyester cord for a belt of a pneumatic tire of the invention has a linear density of 2000 to 16000 Denier and comprises 2 to 9 yarns. The yarns have substantially the same twist as the cords and the cord has a twist of 2 to 7 TPI and a twist multiplier of 3 to 5. In one illustrated  
15 embodiment, the cord comprises 2 to 3 yarns, has a linear density of 2000 to 4000 Denier, a twist multiplier of 3.5 to 4.5 and a twist of 4.5 to 6.5 TPI. In another illustrated embodiment the cord comprises 3 to 9 yarns, has a Denier of 10000 to 15000, a twist multiplier of 3.5 to  
20 4.5 and a twist of 2.2 to 3.2 TPI. In a third embodiment, the cord comprises 6-9 yarns, has a Denier of 11000 to 13000, a twist multiplier of 3,5 to 4,5 and a twist of 2.5 to 3.0 TPI.

The cord of the invention is preferably made of  
25 polyester such as poly-ethyleneterephthalate (PET) or poly-ethylenenaphthalate (PEN).

Also provided in the invention is a pneumatic tire comprising at least one radial carcass ply, a tread disposed radially outwardly of the crown region of the  
30 carcass and a crown reinforcing structure interposed between the tread portion and the crown region of the carcass in circumferential surrounding relation to the carcass. The crown reinforcing structure of the tire includes a belt assembly having at least a first, radially  
35 innermost and a second, radially outermost belt ply, each of the belt plies comprising reinforcement cords extending parallel to one another in each belt ply, and at least one

- 3 -

belt ply is reinforced with cords made according to the invention. In an illustrated embodiment, the crown reinforcing structure of the tire comprises 2 belt plies wherein the cords of the belt plies have a linear density of 2000 to 4000 Denier and a lateral cord density of 20 to 30 EPI. In a second embodiment, the crown reinforcing structure comprises four belt plies wherein the cords have a linear density of 11000 to 13000 Denier and a lateral cord density in the belt plies of 10 to 15 EPI. In a third embodiment, the crown reinforcing structure comprises 2 belt plies and the cords have a linear density of 11,000 to 13,000 Denier and a lateral cord density in the belt plies of 10 to 15 EPI.

The fabric using the cords has a distance between two neighboring cords (rivet area) far above the minimum distance of .1 mm required for guaranteeing sufficient rubber flow between the cords during calendering; such rubber penetration between the cords is required for cord separation resistance. At the same time the fabric ensures sufficient tire reinforcement strength, which is defined by individual cord strength and lateral cord density.

#### Brief Description of the Drawings

To acquaint persons skilled in the art most closely related to the instant invention, certain preferred embodiments thereof are now described with reference to the annexed drawings. These embodiments are directed towards the construction of polyester cords, as herebelow defined, and they are illustrative and can be modified in numerous ways within the scope of the invention defined in the claims herebelow.

Figure 1 is a cross-sectional view of the right side of a pneumatic tire made in accordance with the present invention;

Figure 2 is a side view of a cord according to the present invention; and

Figures 3 and 4 are schematic representations of

- 4 -

cross-sections of cords according to the present invention.

### Definitions

As used herein and in the claims, the "equatorial  
5 plane" of the tire is a plane that is perpendicular to the  
axis of rotation of the tire and passes through the center  
of the tire tread, the terms "axial" and "axially" refer  
to directions which are parallel to the axis of rotation of  
the tire and the terms "radial" and "radially" refer to  
10 directions that are radially toward or away from the axis  
of rotation of the tire. "Denier" is understood to mean  
the weight in grams of 9,000 meters of a yarn before the  
yarn has a twist imparted thereto.

### Detailed Description of the Invention

With reference to Figure 1, there is represented a  
portion of a radial carcass pneumatic tire 10 having a pair  
of substantially inextensible bead cores 11 which are  
axially spaced apart with four radial carcass plies 12  
20 extending between the bead cores 11. The carcass plies are  
folded axially and radially outwardly about each of the  
bead cores and are reinforced by cords which are  
substantially parallel to each other and make an angle with  
the equatorial plane (EP) of the tire. The cords of the  
25 carcass plies 12 can be made of any suitable material, for  
example steel, rayon, polyester, polyamide or aromatic  
polyamide. The crown area 14 of the tire 10 is reinforced  
by a belt assembly 15 located radially inwardly of the tire  
tread 13.

30 The belt assembly 15 is essentially rigid and  
comprises four concentric belt plies 16, 17, 18, 19, each  
of which consists of an elastomeric layer reinforced by  
polyester cords. The polyester may be polyethylene-  
naphthalate (PEN) or polyethylene-terephthalate (PET).  
35 Within each ply, the cords are substantially parallel to  
each other. In the instant case, where the tire has four  
belts, the cords of the radially innermost belt ply 19 make

- 5 -

e.g. an angle of about 20°, cords in breakers 18 and 17 make angles of respectively about -20° and 20°, and the cords of the radially outermost belt ply 16 make an angle of about -20°, all with respect to the equatorial plane (EP) of the cured tire.

In an alternative embodiment where the tire has two belt plies, the cords of the radially innermost belt ply 19 may make an angle of 15° to 30° with the equatorial plane (EP) of the cured tire, whereas the cords of the radially outermost belt ply 16 will extend in the diagonally opposite direction to the cords of the radially innermost belt ply 19, i.e. the cords make an angle of -15° to -30° with the equatorial plane (EP) of the cured tire; preferred cord angles are respectively 17° to 23° and -17° to -23°.

Referring now to Figure 2, there is shown a cord 20 according to the invention comprising two yarns 21, 22 having each a linear density of 1,000 Denier and being twisted at 6.5 TPI; each of the yarns comprises a plurality of polyester filaments 23. The cord is obtained by twisting the yarns at 6.5 TPI at a hand opposite to the one of the cords. The twist multiplier of this cord is about 4. Such a cord is appropriate for reinforcing belts of rear tractor tires. It is recommended to use a cord density of about 25 ends per inch (EPI).

In the cord 20, each of the yarns has its component filaments twisted together a given number of turns per unit of length of the yarn (usually expressed in turns per inch or TPI) and additionally the individual yarns are twisted together a given number of turns per unit of length of the cord. The direction of twist refers to the direction of slope of the spirals of a yarn or cord when it is held vertically. If the slope of the spirals conform in direction to the slope of the letter "S", then the twist is called "S" or "left hand". If the slope of the spirals conform in direction to the slope of the letter "Z", then the twist is called "Z" or "right hand". An "S" or "left hand" twist direction is understood to be an opposite

- 6 -

direction from a "Z" or "right hand" twist. "Yarn twist" is understood to mean the twist imparted to a yarn before the yarn is incorporated into a cord, and "cord twist" is understood to mean the twist imparted to two or more yarns when they are twisted together with one another to form a cord.

In an embodiment of the invention, as shown in Figure 3, two 1000 Denier yarns 31 and 32 are each twisted in the direction indicated by arrows 35 at 6.5 TPI and the yarns are then twisted into a cord in the direction indicated by arrow 36 at 6.5 TPI to form cord 30. The cord 30 has a twist multiplier of about 4. Such a cord is adapted as reinforcement for belts of farm tires. It is recommended in this case to use a lateral density of 25 to 30 EPI.

With reference to Figure 4, there is shown a 3900/3 Denier cord 40, including three yarns 41, 42 and 43. The yarns are twisted in the direction indicated by arrows 45 at 2.7 TPI and the yarns are then twisted together in the direction indicated by arrow 46 at 2.7 TPI. The cord has a twist multiplier of about 4. Such cord may advantageously be used in harvesting tires of size 650/75 R 32 wherein the cords have a lateral density of 13 EPI. The resulting fabric has equal strength per equal surface to currently used belts and improves the belt layout by adding belt gauge at the tire tread area, while at the same time reducing material cost.

Though the invention can be used in cords having only a few thousand Denier, it is with giant cords of more than 8000 Denier that the advantage of reduced cost, tensile strength, modulus and low shrinkage is most significant.

According to the invention, the yarns each have a twist of at least 2 TPI and more preferably of at least 2.5 TPI. The maximum twist which should be imparted to the yarns is 3 TPI, preferably 2.7 TPI. Identical twist of the yarns, although not compulsory to implement the invention, simplifies the manufacturing process. The cord has a twist in the range of 2 to 4 TPI and more preferably in the range



- 7 -

of 2.4 to 3 TPI. The amount of twist of the cord and of the yarns can be substantially the same. The yarns have the same, left or right hand twist, the cord twist being in the opposite direction. Cords manufactured from yarns  
5 having such high linear density and such low twist imparted thereto, have shown the required tensile, modulus and shrinkage properties.

A cord according to the present invention has a twist multiplier between 3 and 5 and preferably between 3.5 and  
10 4.5. "Twist multiplier" refers to a number that is an indicator of the helix angle that the yarns in a cord make with respect to a longitudinal axis of a cord. As used herein and in the claims, the twist multiplier of a cord is determined according to the following equation which is  
15 well known in the textile art.

$$TM = 0.0137 CT \times (CD)^{1/2}$$

wherein TM is the twist multiplier;

CT is the number of turns per inch (2.54 cm) of cord length; and

20 CD is the sum of the deniers of the yarns, and/or subgroups of the yarns of the cord before any twist is imparted to the yarns or subgroups. The twist multiplier is an important feature of a cord, because it characterizes its physical properties, like tensile strength, modulus,  
25 elongation and fatigue. Twist multipliers below 5 characterize cords showing high modulus, high tensile strength, high dimensional stability and low shrinkage; and although these cords have a relatively low fatigue  
[ resistance these cords can be used as belt reinforcement in  
30 agricultural and industrial tires.

The benefits of the present invention become apparent from a comparison test which has been made on aramid and polyester cords according to the invention:

- 8 -

TEST RESULTS		
Construction Twist	Polyester 3900/3 2.7/2.7	Aramid 1500/3 6.9/6.9
<u>Dipped Cord</u>		
Tensile (N)	851.5	755.8
Elongation (%)	18.12	5.58
Lase 1% (N)	91.5	97.1
2% (N)	146.2	225.6
3% (N)	183.4	357.2
4% (N)	217.9	505.5
5% (N)	256.3	654.5
6% (N)	298.8	/
Shrinkage Tot. (%)	1.25	/
Perm (%)	1.12	/
Gauge (mm)	1.40	0.86
*) Pull-out adhesion test (N)	207.4	163.3

\*) All adhesion tests are compared in same rubber compounds.

#### DIPPED PROPERTIES

Construction Twist (TPI)	1000/2 PET 6.5/6.5	1650/2 RAYON 9/9	1300/3 PET 4.5/4.5	2200/3 RAYON 6.5/6.5
Dipping cond. (Tens. g)	1325/375	1100/1500	2300/650	850/ 850
Stretch (%)	+1.6/-2.2	+3.0/-0.5	+1.5/-2.5	+2.0/-0.5
Tensile (N)	151.0	180	293.7	350
Elong. (%)	12.48	9.0	14.69	14.0
Lase 1% (N)	18.8	37.4	34.8	51.3
2% (N)	32.4	73.5	58.3	108.0
3% (N)	44.1	103.2	77.7	155.0
4% (N)	56.1	125.8	97.3	190.8
5% (N)	69.1	-	119.6	-
10% (N)	139.3	-	251.7	-
Work to Brk (Nm)	2.652	2.54	6.276	8.60
Dtex Dry	2535	3630	5018	7320
Gauge (mm)	0.53	0.71	0.79	0.97
*) Pull out adhesion test (N)	176.1	180	178.2	180

\*) All adhesion tests are compared in same rubber compounds.  
All linear densities are given in Denier; 1.1 dtex equal 1 Denier.

- 9 -

The above results clearly demonstrate the superior strength/weight performance of tire cords manufactured according to the teaching of the invention when replacing rayon by polyester. When replacing aramid by polyester, cost is the major advantage, but the polyester also shows higher elongation at break.

In the tables, "Elongation" is the maximum length of the cord at break, "Tensile" is the maximum force applied to the cord at break, "Lase" is the load in Newtons at specified elongation (in percent), and "Shrinkage" is the length change in percent, after heat exposure (curing conditions) under minimum applied force.

The use of PET material according to the invention in farm tires of dimension 18.4R38 STR leads to the following results showing an improved stability of the crown dimensions:

18.4R38 STR	Rayon	HMLS PET	HMLS PET	HMLS PET LOW TWIST ACC. INVENTION
	2440/3 6.5/6.5 18EPI	1440/3 8/8TPI 22EPI	1440/2/2 5/6TPI 18EPI	1440/3 4.5/4.5TPI 20EPI
NSK	51	51	51	52
0 km OD	1745	1732	1728	1726
SD	478	482	475	476
NSK	48	48	47	48
20.000 km OD	1739	1729	1719	1720
SD	482	483	488	476
Corrected OD (20.000)	1745	1735	1727	1726
Conclusion				
OD%	0	+0.2	-0.1	0
SD%	+0.8	+0.2	+2.7	0

NSK - means nonskid or depth of the grooves in the tire.  
 OD - means the maximum overall diameter of the tire.  
 SD - means the maximum distance separating the laterally outer portions of the tire sidewalls.

- 10 -

While the invention has been variously illustrated and described, those skilled in the art will recognize that the invention can be variously modified and practiced. The invention is limited only by the following claims.

- 11 -

WHAT IS CLAIMED IS:

- 5           1.   Cord for a belt of a pneumatic tire made of polyester characterized by;  
            the cord having a linear density of 2000 to 16000 Denier and comprising 2 to 9 yarns;  
            the yarns having substantially the same twist as the  
10           cords; and  
            the cord having a twist of 2 to 7 TPI and a twist multiplier of 3 to 5.
2.   The cord according to claim 1, wherein the cord  
15           comprising 2 to 3 yarns, characterized by a linear density ranging between 2000 to 4000 Denier, a twist multiplier ranging between 3.5 and 4.5 and a twist of 4.5 to 6.5 TPI.
3.   The cord according to claim 1, characterized by  
20           the cord comprising 3 to 9 yarns, having a Denier of 10000 to 15000, a twist multiplier of 3.5 to 4.5 and a twist of 2.2 to 3.2 TPI.
4.   The cord according to claim 1, characterized by  
25           the cord comprising 6-9 yarns, having a Denier of 11000 to 13000, a twist multiplier of 3.5 to 4.5 and a twist of 2.5 to 3.0 TPI.
5.   The cord according to claim 1, 2 or 3  
30           characterized in that the cord is selected from the group consisting of the poly-ethyleneterephthalate and poly-ethylenenaphthalate.
6.   A pneumatic tire comprising at least one radial  
35           carcass ply, a tread disposed radially outwardly of the crown region of the carcass and a crown reinforcing

- 12 -

structure interposed between the tread portion and the crown region of the carcass in circumferential surrounding relation to the carcass, whereby the crown reinforcing structure includes a belt assembly having at least a first, 5 radially innermost and a second, radially outermost belt ply, each of the belt plies comprising reinforcement cords extending parallel to one another in each belt ply, characterized in that at least one belt ply is reinforced with a polyester cord having a linear density of 2000 to 10 16000 Denier and comprising 2 to 9 yarns, wherein the yarns have substantially the same twist as the cords and the cord has a twist of 2 to 7 TPI and a twist multiplier of 3 to 5.

7. A pneumatic tire according to claim 6, wherein 15 the crown reinforcing structure comprises 2 belt plies and characterized in that the cords have a linear density of 2000 to 4000 Denier and a lateral cord density of 20 to 30 EPI.

20 8. A pneumatic tire according to claim 6, wherein the crown reinforcing structure comprises four belt plies and characterized in that the cords have a linear density of 11000 to 13000 Denier and a lateral cord density in the belt plies of 10 to 15 EPI.

25 9. A pneumatic tire according to claim 6, wherein the crown reinforcing structure comprises 2 belt plies and characterized in that the cords have a linear density of 11,000 to 13,000 Denier and a lateral cord density in the 30 belt plies of 10 to 15 EPI.

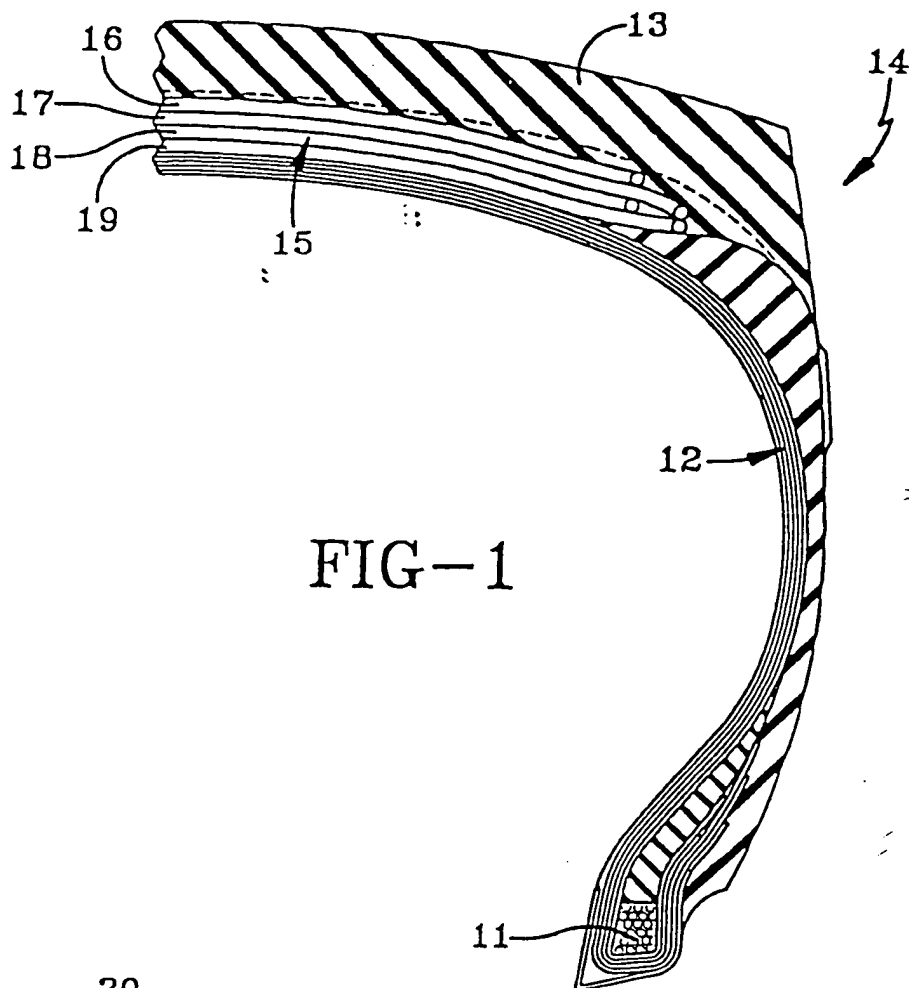


FIG-1

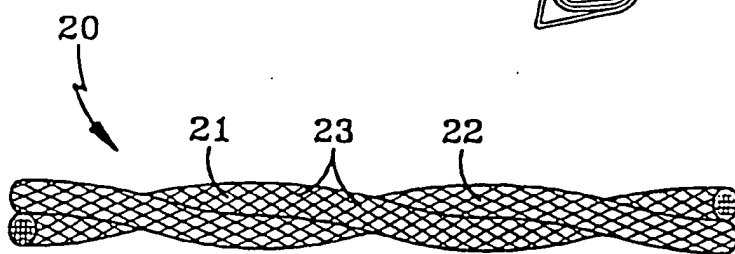


FIG-2

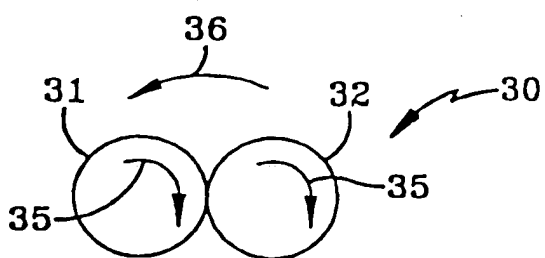


FIG-3

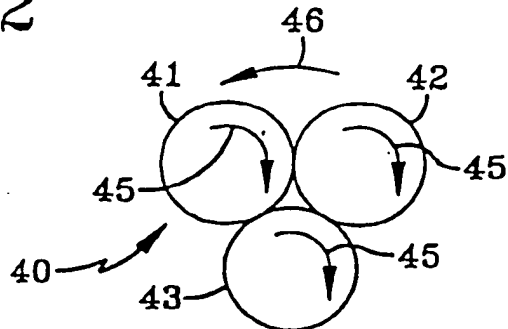


FIG-4

# INTERNATIONAL SEARCH REPORT

Int. Application No

PCT/US 97/15402

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 B60C9/00 B60C9/20 D02G3/48

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 977 172 A (J.N. KERAWALLA) 31 August 1976 see claims	1,2,6,7
A	DE 32 07 826 A (THE TOYO RUBBER INDUSTRY CO. LTD.) 23 September 1982 see the whole document	1,2,6,7
A	EP 0 715 971 A (BRIDGESTONE CORPORATION) 12 June 1996 see claim 1	1,2,6,7
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, A	<p>           DATABASE WPI            Section Ch, Week 9715            Derwent Publications Ltd., London, GB;            Class A95, AN 97-160731            XP002050974            &amp; JP 09 030 210 A (BRIDGESTONE CORP) , 4            February 1997            see abstract         </p>	1-9

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